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How to Grow Rice in the Sacramento Valley

THE COMMERCIAL PRODUCTION of rice in California began in 1912, when 1,400 acres were grown. By 1920 the area had increased to 162,000 acres. The annual rice acreage fluctuates, but averages about 127,000 acres.

Rice growing in California is confined largely to the heavy clay and clay-adobe soils of the lower Sacramento Valley, where a reliable supply of water is available for irrigation. Rice requires high temperatures during the growing season, a dependable water supply for irrigation, level land with an impervious subsoil, and good surface drainage.

Fields on which rice is to be grown should be level and the checks laid out carefully, so that water can be applied to them easily and uniformly. Uneven submergence of rice is likely to cause uneven ripening, which lowers the market value of the crop.

Land on which rice is to be sown is usually spring plowed and then harrowed or the clods crushed with heavy wooden or iron drags. The seed is ordinarily drilled on new land and sown broadcast on old land. If the land is to be submerged continuously in order to control water grass, the seed should be sown broadcast in the water or on the surface of the soil. Seed sown in the water is seldom covered by clods, while that sown on the surface of the soil is frequently covered by slacked clods which prevent normal germination and thus often cause poor stands. Early shallow seeding of drilled rice at the rate of 120 to 130 pounds per acre on new land and 145 to 160 pounds on the old land, to be continuously submerged, and 130 to 150 pounds on old land, sown in the water, usually gives the best results. The leading varieties of rice now grown in California are Caloro, Colusa (C. I. 1600), Early Wataribune, and Onsen.

Weeds, particularly water grasses, are the most troublesome pests in California rice fields. They can be controlled to a considerable extent by seeding in the water or by continuous submergence after broadcast seeding.

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HOW TO GROW RICE IN THE SACRAMENTO VALLEY[1]

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HISTORY

INVESTIGATIONS begun by the United States Department of Agriculture in the spring of 1909 and continued for three years provided information which indicated the commercial possibilities of rice culture in California. The first commercial rice crop was grown in California in 1912 on Stockton clay-adobe soil in the Sacramento Valley, near Biggs. The high acre yields and large profits from this crop of 1,400 acres received wide publicity, which stimulated interest and resulted in the rapid expansion of the California rice industry. In 1914, 15,000 acres were sown, while in 1915 the crop was grown on 34,000 acres. The high price of rice during the World War naturally caused a further increase in acreage and production. The maximum so far was reached in 1920, when 9,720,000 bushels of rice was produced on 162,000 acres. A larger acreage was sown to rice in 1930 than in 1929, the estimate for 1930 being 110,000 acres with a production of 7,271,000 bushels, or about 3,271,950 one hundred-pound bags.

Rice is grown in California largely in the San Joaquin and Sacramento Valleys. Most of the crop is produced in the Sacramento Valley in Butte, Glenn, Colusa, Sutter, and Yolo Counties.

[1] For a more complete discussion of rice production in California, together with the details of the experiments on which many of the recommendations in this bulletin are based, see U. S. Dept. Agr. Bul. 1155, Rice Experiments at the Biggs Rice Field Station in California, and U. S. Dept. Agr. Bul. 1387, Experiments in Rice Culture at the Biggs Rice Field Station in California.

IMPORTANCE OF THE RICE CROP

The area on which rice can be profitably grown in the United States is much more limited than that on which most of the other cereal crops can be produced with profit. Rice is well adapted, however, to certain sections.

During the 5-year period from 1926 to 1930 California produced 18.2 per cent of the total annual rice crop of the United States on 13.2 per cent of the total annual acreage. The average yield per acre in California is considerably higher than that obtained in other large rice-producing States.

In California rice ranks third among cereal crops in total production and also in total value, being exceeded only by wheat and barley. Rice, although occupying about one-eighth of the average barley acreage and less than one-fifth of the average wheat acreage during the 5-year period—1926 to 1930—had a value equal to about 39 per cent of that of the barley crop and about 53 per cent of the value of the wheat crop in California. Rice is grown chiefly on land that was used for wheat and barley prior to the introduction of rice, so that under rice culture this land is much more productive of wealth than it was when wheat and barley were grown.

RICE-GROWING REGIONS

There are three main rice-producing regions in the United States:

(1) The broad level prairie region of southwestern Louisiana and southeastern Texas, where rice growing began on a commercial scale about 1885. The irrigation water for this section is obtained by powerful pumps from sluggish streams or bayous, which provide drainage for the prairies. Water is also pumped from deep wells. This is the most important rice-producing region in the United States.

(2) The prairie region of eastern Arkansas, where rice growing began commercially in 1905. The irrigation water for this section is pumped from wells.

(3) The interior valleys of California, where rice growing began on a commercial scale in 1912. The irrigation water for this section is obtained largely from the Sacramento and Feather Rivers by gravity and pumps.

REQUIREMENTS OF THE CROP

Successful rice culture is dependent upon high temperatures during the growing season, a dependable water supply during the period of irrigation, soils that are comparatively flat or level and underlain with an impervious subsoil, and good surface drainage.

In tropical and subtropical countries rice is the standard cereal crop. About 97 per cent of the world's rice is grown in eastern Asia. Rice is also grown in the warmer sections of the Temperate Zone. India, China, Japan, French Indo-China, Siam, Java, and the Philippine Islands are the leading rice-producing countries of the world.

In California continuous submergence of the land to a depth of 4 to 7 inches for 90 to 140 days each year is necessary for the production of profitable rice crops. Flooding the land to germinate the seed is also necessary if the rice is sown with a drill or broadcast and harrowed. Therefore, a dependable supply of irrigation water must be available.

The clay and clay-adobe soils of California, which have an impervious subsoil from 1½ to 6 feet below the surface, are well suited to rice culture. Such soils require less water to produce a crop than do the lighter soils. After draining in the fall, these heavy soils usually dry out and crust at the surface more quickly than the lighter soils, thus making possible the use of heavy machinery in harvesting the crop. Level land can be prepared for rice irrigation at a much lower cost per acre than slightly rolling or rough land. The larger checks on level land are also more economical to harvest than the small checks necessary on uneven land.

Good drainage is as essential in rice culture as in wheat culture, for without adequate drainage it is difficult to obtain good stands in the spring and practically impossible to drain the land thoroughly for harvest when the crop is nearing maturity. Poorly drained fields are hard to cultivate and expensive to harvest. It is therefore essential to have good surface drainage if maximum yields are to be produced at a minimum cost.

CLIMATE

In the Sacramento and San Joaquin Valleys the summers are hot, with low humidity. The hottest months are June, July, and August, with maximum temperatures ranging from 105° to 115° F. During these months a daily range in temperature of 40° is not uncommon. The nights are comparatively cool, even during the hottest months. The winter months are usually mild, though freezing temperatures are not uncommon during December, January, and February. These are also the months of highest precipitation. All precipitation is in the form of rain. The average annual rainfall at the Biggs Rice Field Station, Biggs, Calif., for the 18-year period from 1913 to 1930 was 20.07 inches.

The average evaporation from a free-water surface from April 1 to October 31, inclusive, for an 8-year period was 42.05 inches. Strong winds seldom occur, though there is often considerable wind during the early spring and late fall months.

SOILS

The rice crop in California is grown on various soil types. The heavy clays and clay adobes which are underlain with an impervious subsoil at depths ranging from 18 to 36 inches appear to be best adapted to this crop. These heavy soil types are hard to cultivate. If plowed when too wet they bake; if too dry they turn in large clods, which are difficult to reduce. These soils require from 4 to 6 acre-feet of water to mature a rice crop, while lighter soils may require from 7 to 10 acre-feet. Heavy soils when drained in the fall usually dry out and crust at the surface in from 10 to 14 days, so that they will support heavy harvesting machinery, while most light soils dry more slowly and do not crust at the surface as quickly, so that it is often necessary to harvest in the mud. Harvesting under such conditions is very expensive.

ROTATIONS

The rice industry of California is comparatively young, and no definite system of rotation is yet being followed. The heavy soils on which rice is grown and the high water table during the submergence season make it difficult to find crops that can be grown profitably in a rotation with rice. The nearest approach to a rotation system at present is on land on which two or three rice crops have been grown. These rice crops are followed by spring or summer plowed fallow on which wheat or barley is fall sown, and then rice is again grown for one year. By this method only one rice crop is grown on the same land once in three years after the original crops on new land. A second method is to alternate a rice crop and fallow. The rice stubble is spring plowed dry for fallow, then prepared for rice the following spring. Some growers do not fallow

FIGURE 1.—Sheep grazing on uncultivated rice land

but leave the land uncropped and uncultivated until it is prepared for rice the following spring. Such lands are often pastured. (Fig. 1.)

At the Biggs Rice Field Station attempts have been made to grow cultivated crops in rotation with rice, but neither corn, grain sorghums, cotton, nor beans have produced a profitable crop. Until more information is available on other crops it seems advisable to use the crops that were produced before rice growing began, i. e., wheat and barley. These crops mature before the water table has risen sufficiently to interfere with growth. Some very good yields of wheat and barley have been reported on fallowed rice land, although some growers do not think that these crops are profitable under such conditions. These growers prefer to alternate rice and fallow or to have two rice crops and one fallow. The growing of wheat or barley following rice without fallowing is seldom practiced, for the yields obtained are usually low.

FERTILIZERS

The three plant-food elements most likely to be deficient in soils are nitrogen, phosphorus, and potash. When deficient, these elements can be added to the soil in the form of manure and commercial fertilizers.

Fertilizers are not extensively used on California rice fields. Each year, however, more growers are making inquiry regarding the possibility of maintaining or increasing yields by the use of fertilizers. The water used for irrigation in California is comparatively pure and therefore adds but little, if any, plant-food elements to the soil.

The new rice lands are very productive, but yields are usually materially lower with each successive crop. The reduced yields may be due to a lack of plant-food elements, competition with weeds, poor physical condition of the soil, lack of humus, poor drainage, unfavorable conditions for soil microorganisms, or other causes.

Fertilizer experiments with rice at the Biggs Rice Field Station indicate that the Stockton clay-adobe soil is deficient in nitrogen. It is quite possible that other rice soils of California are also deficient in this element. Nitrogen can be added to the soil as commercial fertilizer or by growing a leguminous crop to be plowed under. The second method should be followed wherever possible, as it adds humus and thus improves the physical condition of the soil as well as supplying nitrogen. Decaying organic matter also helps to make other plant-food elements more readily available.

Bur clover is the most promising winter-legume crop on California rice lands. It is difficult, however, to obtain a good stand of bur clover on old rice land. Bur clover grows best on well-drained soils. In cold, wet winters the stand and growth of this clover often are very poor. Attempts have been made to obtain stands of bur clover by seeding scarified seed, unscarified seed, or seed in the hulls on fallow land in September. After seeding, the land may be irrigated to germinate the seed and maintain suitable moisture conditions for early growth. In favorable years good stands have been obtained in this way, while in unfavorable years the results have been a failure. Weather conditions must be favorable to get good stands of bur clover. If the weather is too cold or dry and hot following fall irrigations, poor stands are obtained. The germination of bur-clover seed appears to be very uncertain. Most farmers who sow bur-clover seed on fallow land now depend upon rainfall to germinate the seed and maintain suitable moisture conditions for growth. Other farmers irrigate the fallow land in the fall and depend upon the clover seed present in the soil for profitable stands. Fall irrigation also germinates a large quantity of water-grass seed, which is later killed by frost.

At the Biggs Rice Field Station in 1924 a crop of bur clover which stood about 12 inches high was plowed under during seed-bed preparation, and the yield of rice obtained that year on the clover land was about 38 per cent higher than that on fallow land. The rice growers of California appreciate the fact that a good growth of bur clover turned under in the spring materially increases the yield of rice. The difficulty, as stated, is in getting a good stand and growth of clover to be turned under.

Rice yields at the Biggs station have been materially increased by the application, just before seeding, of manure at the rate of 1 ton per acre, of ammonium sulphate at the rate of 100, 150, and 200 pounds per acre, of dried blood at the rate of 160 pounds per acre, and of cottonseed meal at the rate of 280 pounds per acre. The increased yields were sufficient to give a fair profit after deducting the cost of the fertilizer, the cost of its application, and the expense of handling the increase in yields.

Investigations indicate that nitrogen in the form of ammonia is probably best suited for rice, whereas most cultivated plants use nitrogen in the form of nitrates. Rice is normally grown on submerged land which is unfavorable for the existence or formation of nitrates, but some ammonia compounds are formed in and retained by the soil. The applications of nonnitrogenous fertilizers at the Biggs station have failed to increase yields materially. The nitrogenous fertilizers if applied in too great quantity are likely to delay maturity and cause lodging; therefore, they should be used with care.

The fertilizer experiments at Biggs show that for the midseason variety Caloro ammonium sulphate applied at seeding time at the rate of 150 pounds to the acre produced the largest and most profitable increases in yield, whereas for the early-maturing variety Colusa (C. I.[2] 1600) 200 pounds of ammonium sulphate has given the largest net return per acre. For the last few years the application of ammonium sulphate at the rate of 150 pounds at seeding time has been recommended to rice growers, a number of whom now use this fertilizer and consider the practice profitable.

Ammonium sulphate is difficult to apply because of the fineness of the material and because it is hygroscopic. It often takes up moisture and cakes or gets wet enough to bridge over in drills or broadcast seeders. Ammonium sulphate has been applied with lime spreaders and with end-gate seeders, but considerable trouble has been experienced in getting an even distribution, especially with end-gate seeders. Lime spreaders are best for this purpose.

WATER SUPPLY

The Sacramento and Feather Rivers, which are fed by melting snows in the Sierra Nevada Mountains, supply most of the water used for rice irrigation in the Sacramento Valley. Private companies divert the water from these rivers by gravity or by large pumps. The water is distributed to the growers by a system of canals and laterals and sold on an acre-foot basis or at an annual charge per acre. Very little rice is irrigated from deep wells in the Sacramento Valley, but in the San Joaquin Valley deep wells are often the only source of water. Deep wells are expensive to dig, equip, and operate, and should not be depended upon for rice irrigation unless they have been thoroughly tested. If wells are to be used they should be ready to operate before the rice is sown. In California water must be held continuously on the land after broadcast seeding in the water or on the surface of the soil. On new land the seed is usually sown with a grain drill and water is applied to

[2] C. I. refers to the accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

germinate the seed and maintain suitable moisture conditions for growth until the crop is large enough to withstand continuous submergence.

PREPARATION OF LAND FOR IRRIGATION

Most of the land on which rice is grown in California is comparatively level, with a gentle slope varying from 2 to 5 feet per mile. Such land can be prepared for rice irrigation with little expense. A competent surveyor should be employed to locate the supply ditches, the drainage ditches, and the field levees. The improper location of these ditches and levees often causes serious losses. The supply ditches should be properly located and large enough to furnish ample water when needed. The drainage system should be adequate to dispose of the water promptly when desired. The usual method of connecting the various points on a contour line is to follow the rodman with a plow, the plowed furrow indicating the base of the levee. A tractor drawing 10 or 12 plows then makes one round, backfurrowing to the furrow made by the team. This provides loose ground for building the levees. Sharp turns in levees should be avoided when possible, for such turns make the levees hard to build and the crop difficult to harvest.

The outside levees should be well constructed and higher than the field levees, to avoid seepage and loss by overflowing. The outside levees often serve as one bank of the supply or drainage ditch and when so used are often built with a Fresno scraper. The interior or field levees are usually made with a checker drawn by one or two tractors, depending upon the size of the checker or of the tractors used. The checkers are usually equipped with some device for raising and lowering the rear end, which enables the operators to lift it when moving from levee to levee and in a measure to control the size of the levee. When the ground is rough or trashy the checkers are often weighted so that they will push enough soil together to form a good levee. On large fields these outfits can build from 10 to 15 miles of levees in a day.

The checkers are usually homemade and are variable in size. The runners for the sides are generally made of 3-inch by 12-inch plank 16 to 24 feet in length and are lined with steel. The front end is from 10 to 18 feet wide on the bottom, and the rear end is 3 to 6 feet wide on the bottom. The sides are made 2 to 3 feet high and are set on a batter, or slant, of ¼ to 1, the tops sloping outward. A tractor-drawn checker is shown in Figure 2.

It requires more power to pull a large checker than a small one, but the levees constructed by a large checker are much more serviceable and economical than those poorly built with a small checker. Poorly constructed levees often result in low yields of rice of poor quality. Levees on small fields are often built with a ditcher or V crowder.

The checkers are pulled with the wide end forward, the loose surface soil being drawn through to the small end. This makes a levee from 12 to 24 inches high and from 4 to 6 feet wide at the base.

It is impossible to connect the field levees and outside levees with the tractor and checker, owing to the space needed for turning. Therefore, the ends of the field levees must be built to connect with the outside levees by using the Fresno scraper, or a tractor scraper.

Levees on fallow land that have been "knocked down" are sometimes rebuilt in the fall. The winter rains settle these levees and they are in good condition to hold water the next spring. If the rice is sown broadcast in the water it is possible to seed over these levees without causing many breaks, whereas with newly constructed levees it is necessary to seed each check separately.

At convenient places in the levees irrigation boxes should be installed to facilitate irrigating. The boxes should be placed deep enough so that the bottom boards will not hold the water back when the fields are draining. The depth of water is controlled by shutters which are held in a vertical position across the openings of the irrigation boxes. By taking out or putting in a narrow board shutter the water can be lowered or raised as desired.

FIGURE 2.—A tractor-drawn checker used in constructing levees in California rice fields

Leveling the land within a check is not commonly practiced in California. Where high spots are removed to fill in low places, the crop on the fills grows very rank and does not mature well, while on the scraped places the growth is stunted.

On old rice land an unequal depth of submergence in the check does not materially affect the date of maturity of the rice crop, but on new land unequal depths of submergence may result in the uneven ripening and inferior quality of the grain.

SEED-BED PREPARATION

In preparing the seed bed the land should be spring plowed 4 to 6 inches deep as early as it can be worked to advantage. In a week or 10 days after plowing the land may be disked or harrowed. (Fig. 3.) A few days later it is dragged with a heavy drag. If the land is very cloddy, it is often dragged two or three times. Disk-

ing and harrowing are often omitted and the clods are crushed with heavy drags. The time that elapses between plowing and the other cultural operations gives the weather an opportunity to reduce the clods; in fact, the action of the weather on clods during these intervals is often more effective than cultivation in preparing a good seed bed. A light rain followed by a few warm days is very effective in reducing clods.

Very little California rice land is fall plowed. The reason for this is that rice is harvested late in the fall, in October and November, and rains may occur before threshing is completed. By the time harvest is completed the land is usually too wet to plow. Some rice land is fall plowed in exceptionally dry years. Fall-plowed land, through the action of rain and sun during the winter months, is easily reduced to a good seed bed during the following

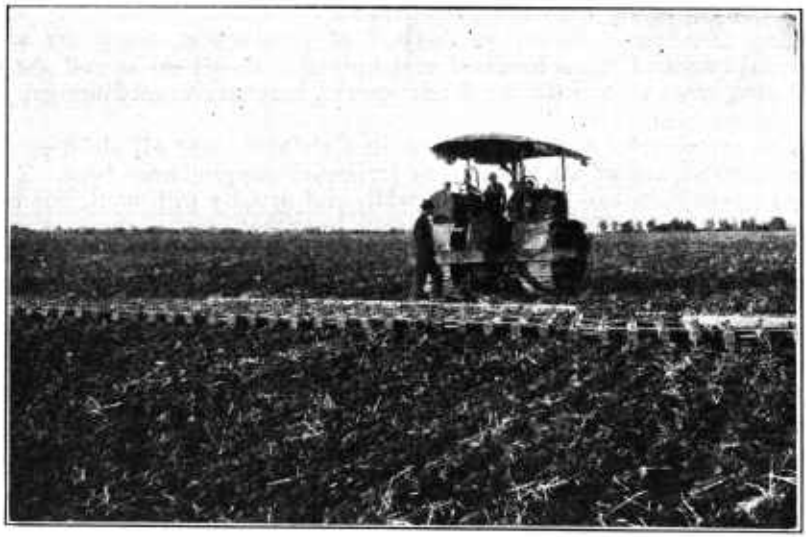

FIGURE 3.—A heavy, spike-tooth harrow sometimes used in seed-bed preparation in California rice fields

spring. On the other hand, weeds, especially canary grass and wild oats, start growth on fall plowing during the late winter and early spring months and are difficult to kill unless the land is replowed shallow in the spring, which makes the seed-bed preparation expensive. If weed growth is killed on fall-plowed land before sowing, the cost of preparing a seed bed on spring-plowed and on fall-plowed land is about equal. Yields at the Biggs station have been similar on fall and spring plowing.

A slightly rough seed bed is preferable to a finely pulverized one for drilled rice. Finely pulverized seed beds have a tendency to run together after irrigation and remain cold and unfavorable for germination and early growth, while one that is slightly rough does not run together so much and is more favorable for germination and early growth. A fine seed bed is desirable when the rice is sown broadcast and continuously submerged to control water grass. There is less danger of seed being buried by slacked clods on smooth than

on rough seed beds. Rice seed covered with soil and water does not germinate well, and if buried too deep it rots. A rough seed bed is not objectionable if the seed is sown in the water, because the water slacks the clods before the seed is sown, so that there is little danger of the seed being buried with soil and water.

Rice sown on disked stubble does not yield so well as that on plowed land. The disked stubble land provides better conditions for the growth of cattails, spike rush, umbrella plants, and other weed pests. Skips in a plowed field usually can be detected in the growing crop by the presence of cattails and spike rush (wire grass). It pays to kill all growth before sowing rice.

VARIETIES TO GROW

There are two main groups of rice—glutinous and nonglutinous. The nonglutinous rices are grown most extensively in all rice-producing countries. Based on method of production, there are two general types of rice—lowland and upland. Based on kernel shape and size, rices are classed as slender-grain, long-grain, medium-grain, and short-grain varieties.

The commercial varieties grown in California are all short-grain rices, and all are of the lowland or irrigated nonglutinous type. The short-grain rices are hardy, yield well, and usually mill well, but the best varieties require a comparatively long growing season. Early rices are desirable in California, but in addition to earliness they must have stiff straw and the ability to produce high yields of good milling quality.

Many early rice varieties are known, but earliness, stiff straw, high yield, and good milling quality are seldom combined in one variety. Earliness is easy to secure, but the desirable combination of other characteristics with it is hard to find. Earliness in rice, as in most crops, is often associated with low yields and inferior quality instead of high yields and good quality.

The varietal experiments at the Biggs Rice Field Station show that the short-grain rices are better adapted to California conditions than the medium or long grain varieties. The early and mid-season short-grain varieties are grown most extensively in California and produce much better crops than the medium and long grain rices.

A variety of rice known to be adapted to the section in which it is to be grown should be sown in preference to some new and unknown variety. New varieties should not be sown extensively until they have been tested in comparison with the leading local varieties. Frequently the sowing of a new variety before it has been tested results in considerable loss to the growers. The new variety may not be adapted to the section, or may have a weak straw, or may produce low yields of poor quality. It is best to use home-grown seed of an adapted variety that is known to produce good yields of good quality.

The commercial varieties in California are often badly mixed. The varieties become mixed from volunteer growth when growers change varieties. The varieties are also mixed in threshing when a grower produces more than one variety. These mixtures are undesirable because the different varieties usually vary in kernel size and mature at different dates, which results in an inferior quality of rice.

It would probably pay growers to maintain seed plots on their farms on which they could rogue out the mixed varieties and inferior plants. If the crop from such plots is carefully threshed and cleaned, growers could produce their own seed of a known variety of good quality and free from mixtures. Growers who do not wish to take the trouble to raise seed rice in a seed plot usually can obtain good seed from some one who specializes in seed production. It is discouraging to see a pure-line variety, the development of which has required the spending of considerable time and money, become badly mixed after being grown commercially for two or three years.

The leading varieties of rice in California are discussed in the paragraphs that follow:

CALORO

Caloro rice was developed at the Biggs Rice Field Station and was first distributed in 1921. It is now the leading variety grown in

FIGURE 4.—Seed rice of the Colusa variety. (Natural size)

California. It is a pure-line variety which heads and ripens uniformly and yields well on both new and old land. It matures about four days earlier than Early Wataribune. The grains are short and broad and, like those of Early Wataribune, have short yellowish beards, which usually drop before the crop is harvested and threshed. Caloro heads quickly, ripens evenly, and usually yields better than Early Wataribune. On old rice land Caloro requires about 155 days from the first irrigation until the crop is mature. In 1929, Caloro was grown on about 80 per cent of the California rice acreage.

COLUSA

The Colusa variety (C. I. 1600) is an early, short-grain rice distributed by the Biggs Rice Field Station. (Fig. 4.) It was developed from a selection originally made at the Crowley Rice Experi-

ment Station, Crowley, La. Colusa is 10 days to two weeks earlier than Early Wataribune, requiring about 145 days from the first irrigation until the crop is mature on old rice land. It yields well on new land but not on old rice land unless the latter is quite productive. Colusa is especially well adapted for growing on new land, but is inclined to lodge if the land is very rich. The grains are short and broad, light yellow, and beardless. In 1929, Colusa was grown on 14 per cent of the California rice acreage.

EARLY WATARIBUNE

Early Wataribune was one of the leading varieties in California. This variety was introduced from Japan by W. K. Brown in 1913. It is not a pure variety, but is slightly mixed and consequently does not head and mature uniformly. Early Wataribune yields well on

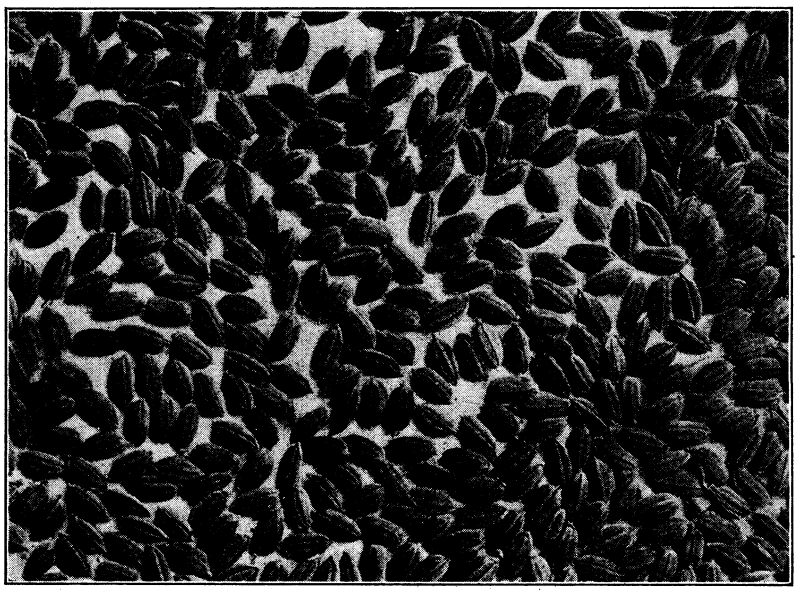

FIGURE 5.—Seed rice of the Wataribune variety. (Natural size)

new and on old land and matures about a week to 10 days earlier than Wataribune. It mills well and is popular with both growers and millers. On old land it requires about 158 days from the first irrigation until the crop is mature.

The grain of Early Wataribune is short and broad. The hull is light yellow and has a light-yellowish beard. The beards usually drop before the rice is harvested or at harvest time, so that the threshed rice is mostly beardless. (Fig. 5.)

IMPROVED CALORO (SELECTION No. 175)

Improved Caloro (Selection No. 175) is a pure-line selection which has given slightly higher average yields than Caloro at the Biggs Rice Field Station. This variety was distributed by the station in 1927 and at present is being grown on commercial fields. Improved Caloro is a midseason, partly awned variety, which heads and ripens

uniformly, both on new and old land. It matures at the same time as Caloro. When distributed by the station it was free of mixtures. The variety was distributed with the thought that it could replace with profit that part of the Caloro variety which has become badly mixed with other varieties, including red rice.

ONSEN

The Onsen variety is an early short-grain rice introduced from Japan by a Japanese in 1918. Onsen is about two weeks earlier than Early Wataribune and yields well on new land but has a marked tendency to lodge. On old land Onsen does not, as a rule, yield as well as Early Wataribune or Caloro, but appears to be better adapted in some sections than Colusa. Onsen is not a pure-line variety but is mixed. Most of the crop is very similar to Colusa, though the grains may be slightly larger. They are short and broad, mostly beardless, and the hull is light yellow. On old rice land Onsen requires about 142 days from the first irrigation until the crop is mature.

SEED

After deciding upon the proper variety to grow, one which is adapted to the locality, has stiff straw, and yields and mills well, it is important to have a supply of good seed of that variety. Good seed rice should be graded and cleaned with a fanning mill. It should be free from red, immature, hulled, or broken rice or the seeds of other rice varieties or weeds. Good seed rice should be well filled and uniform in size. Uniformity in size and ripening is more important in rice than in other cereals, because the value of rough rice is based upon the percentage of head rice obtained in milling. Larger yields of head rice are obtained from well-matured rough rice consisting of grains of uniform size of one variety than from poorly matured rough rice consisting of grains of various sizes and a mixture of varieties.

The use of seed rice containing immature, hulled, or cracked grains often results in poor stands which ripen unevenly and produce low acre yields of inferior quality. Grasses and weeds increase the cost of production, reduce yields, and lower the market value of the crop produced. (Fig. 6.)

Mixed varieties that mature at different times and vary in kernel size are very undesirable in rice.

Poor stands often can be improved by sowing in an early-maturing variety of the same type as that originally sown, but this practice is not to be recommended except in extreme cases, and the crop produced should not be used for seed the following year. Economy in crop production is desirable, but it is false economy to use poor seed rather than to pay a slightly higher price for good seed.

During the last few years red rice has been increasing in the California rice area. Two varieties of red rice are present, namely, the southern red rice, which has a spreading growth habit and a short grain very much like that of the short-grain rices, and the so-called Italian red rice, which matures early, has a larger grain than the short-grain rices, and is erect in growth. The latter has purplish-black awns and culm joints and is easily detected in rice fields after it has headed. Red rice can be eradicated in California by using

seed that is free of red rice. Seed rice containing red rice should not be sown, for red rice materially reduces the market value of the rice crop.

If there is any doubt regarding the germination of the seed, it should be tested before it is sown. To make a germination test, count out several lots of 100 seeds from the seed to be sown. Place the lots separately in jars containing fresh water and keep them at a temperature of approximately 75° F. for about 10 days. Then count the seeds that have strong sprouts and figure the percentage of germination. Conditions are less favorable for germination under water than in moist soil or between blotting papers, therefore it is advisable to make the germination test in water if the seed is to be sown broadcast in water or submerged immediately after seeding. If seed of low germinating power must be used, the rate of seeding

FIGURE 6.—Seed rice of the Wataribune variety, containing weed seeds. (Natural size)

should be increased materially. The California State Department of Agriculture at Sacramento will make germination tests if samples accompany the request.

SEEDING

METHOD OF SEEDING

Rice is sown with a grain drill or broadcast with an end-gate seeder. (Fig. 7.) All rice is now sown with an end-gate seeder except on new land or land that is known to be free of water grass. On rough seed beds drilling is slow and expensive, and the seed is not placed at a uniform depth or covered evenly. Even on good seed beds drilling is slow and expensive, although the seeding is uniform. Broadcasting is rapid and inexpensive, but the seeding is not uniform. Rice sown broadcast should never be harrowed if the land is to be submerged continuously after seeding.

In 1929 a section of land near Merced, Calif., on which the stand of rice was practically a failure because the seed was eaten by mud hens, was resown in the water by airplane. A fairly good crop was harvested. In 1930, several rice growers used airplanes to sow their rice in the water and satisfactory stands and yields were obtained. In California the use of airplanes for this purpose has promising possibilities if the cost of seeding by this method is not too expensive as compared with the cost when horses or mules or tractors are used. (Fig. 8.)

DATE OF SEEDING

The best date to sow rice in California varies with the soil and climatic conditions from year to year. Rice may be sown between April 15 and June 1, but for the best results with all methods of irrigation and when soil conditions and temperature permit, it

FIGURE 7.—Rice being sown in the water with an end-gate seeder with horses

should be sown as early as possible. There is less danger of losses from fall rains when the crop is sown early.

A variety of rice has a tendency to mature within a certain period regardless of the date of seeding, but yields are higher from the early dates of seeding. In a date-of-seeding experiment at the Biggs Rice Field Station in which Wataribune rice was sown as early as soil conditions permitted and at 15-day intervals thereafter until June 1 there was a marked decrease in yield with each successive date of seeding.

The earliest date of seeding produced a 9-year average of 400 pounds per acre more than the second date, and 500 pounds per acre more than the third date. The late-sown rice was of poorer quality each year than the early-sown rice.

It has been observed also that early-sown commercial fields as a rule produce higher yields of better quality than late-sown fields.

Light soils are warmer early in the spring than heavy soils and for this reason can be sown earlier. Rice sown on a cold soil and

irrigated with cold water during a period of low temperatures usually germinates slowly, and often three weeks elapse before the plants emerge. Under such circumstances seeding should possibly be deferred until conditions are more favorable for germination and growth. Under such variable conditions as exist in California no best date of seeding can be recommended. However, late-maturing varieties should be sown as early as weather and soil conditions

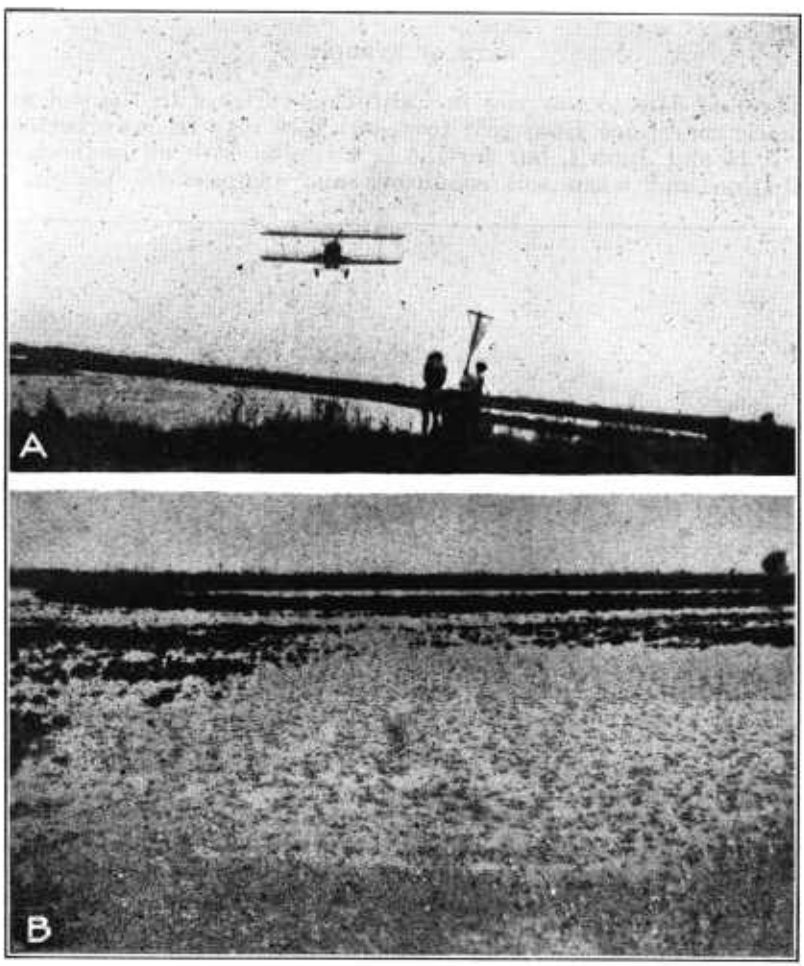

FIGURE 8.—A, Rice field being sown by an airplane; airplane seen approaching a flagman; B, seed rice dropping in the water from an airplane

permit, from April 10 to 25, midseason varieties may be sown from April 15 to May 15, and early varieties from April 20 to May 20.

RATE OF SEEDING

The rate of seeding depends upon—

(1) The variety used. Early-maturing varieties stool less than late-maturing ones, and for this reason more seed should be sown.

(2) Quality of seed used. Poorly matured seed does not germinate so well as fully matured seed, and for this reason seed of inferior vitality should be sown at a higher rate than well-matured seed.

(3) Fertility of the soil. Less seed is required on rich soils than on poor ones, because the crop will stool more on rich soil.

(4) Condition of the seed bed. Less seed is required on a well-prepared seed bed than on a poorly prepared one, because the percentage of germination is higher on the former.

(5) Method of irrigation. Good stands of drilled rice are dependent upon proper irrigation when the crop is being irrigated up. Small heads of water during the initial floodings often result in poor stands, owing to the long time required to cover and drain the fields. If the fields are to be continuously submerged, the rate of seeding should be heavier than when the rice is drilled and irrigated and drained at frequent intervals.

(6) Date of seeding. Less seed is required to obtain an optimum stand of drilled rice late in the season than earlier, for conditions are then more favorable for prompt germination and growth.

(7) Method of seeding. As a rule, less seed is required on well-prepared seed beds when drilled than when sown broadcast and continuously submerged.

(8) Drainage. Good drainage is essential to obtain good stands. If the drainage is poor the rate of seeding should be increased, so that if some of the seed rots there will be less injury to the stands.

(9) New or old land. Less seed is required to obtain optimum stands on new than on old rice land, because conditions are more favorable for germination and the rice stools better. Thin stands may induce excessive stooling, resulting in nonuniform heading and ripening and often in low yields of poor quality. Good stands prevent excessive stooling, aid in the control of weeds, and tend to produce uniform heading and ripening and high yields of good quality.

Late-maturing varieties, if drilled, should be sown at the rate of 115 to 125 pounds per acre on new land, 125 to 135 pounds per acre on old land; if broadcast, 145 to 160 pounds per acre on old land to be continuously submerged and 130 to 150 pounds per acre when sown in the water. Midseason varieties, if drilled, should be sown at the rate of 120 to 130 pounds per acre on new land, 130 to 140 pounds per acre on old land; if broadcast, 150 to 160 pounds per acre on old land to be continuously submerged and 135 to 150 pounds per acre when sown in the water. Early varieties, if drilled, should be sown at the rate of 125 to 135 pounds per acre on new land, 135 to 145 pounds per acre on old land; if broadcast, 150 to 160 pounds per acre on old land to be continuously submerged and 140 to 150 pounds per acre if sown in the water. In sowing rice in the water, wagons and 2-wheeled carts made from the back wheels of an ordinary wagon are used. A bed is built on these carts to hold the endgate seeder and 8 or 10 sacks of seed rice. The carts are drawn by three or four horses abreast or by tractors.

DEPTH OF SEEDING

The depth at which rice should be drilled depends upon—

(1) Character of the soil. Rice can be sown deeper on a light warm soil than on a heavy cold one, because the seed will germinate and emerge more quickly.

(2) Condition of the seed bed. On poorly prepared seed beds the seed should be sown shallower than on well-prepared beds, because if sown 2 inches deep on a poorly prepared seed bed the first irrigation water will slack the clods and cover the seed to a depth of perhaps 3 to 4 inches, which is too deep for best results.

(3) Drainage. On land that can not be well and promptly drained, shallow seeding is preferable to deep seeding, because rice covered with soil and water germinates poorly and much of the seed rots, but it germinates well under

water if the seed is not covered with soil and conditions are favorable for germination. On land to be continuously submerged the seed should never be covered with soil.

IRRIGATION

On the heavy soils used for rice culture in California it is necessary to apply water to germinate the seed. The usual irrigation season for drilled rice is therefore divided into two periods. The first period consists of frequent irrigations, followed by drainage, to germinate the seed and to keep the crop growing well until about 30 days after emergence, when the second period, or period of submergence, should begin. Good stands are occasionally obtained by early seeding on light soils without irrigation to germinate the seed, but such cases are rare. On heavy soils rice should not be sown until water for irrigation is available.

During the first irrigation period when the water is applied to start germination, the water, soil, and air temperatures are usually much lower than they should be to insure prompt germination. Usually two irrigations are necessary to get the plants up. With the first irrigation it is not so essential that the water be drained from the field quickly, though it should not remain on the land more than two and one-half days. After the first irrigation the soil should not be allowed to dry out enough to injure the germinating seeds.

The second irrigation is the critical one, and unless the field is irrigated quickly and drained promptly the stands obtained are very likely to be thin and disappointing. When the crop is up it should receive frequent irrigations to keep the soil in good condition for growth. This will require an irrigation once each week or 10 days, depending upon the soil and climatic conditions, until the rice is submerged. At the last irrigation preceding submergence, the water should be drained off very slowly in order to stretch the plants in the low spots so that they will not be injured by deep water when submergence begins.

Irrigation experiments at the Biggs Rice Field Station show that for drilled rice the land should be submerged to a depth of 6 inches 30 days after the plants have emerged. During the submergence period enough water should be entering the checks at all times to replace the losses by seepage, evaporation, and transpiration, and to maintain the desired depth of submergence.

When the rice is submerged, water flows from check to check, and normally there is little danger of any part of the field becoming stagnant if the water is maintained at a constant depth. Therefore it is not necessary, on lands that are free from alkali, to have water overflowing the last check into a drainage ditch. Water is valuable and should not be wasted in this way.

Profitable rice crops can not be grown in California without submerging the land continuously for 90 to 140 days. Rice grown on land kept moist but not submerged is dwarfed and produces small heads and low yields of poor quality.

The control of water grass by continuous submergence is now used extensively in California. The rice is sown broadcast either on the surface of the soil or in the water after the fields are submerged. When the rice is sown on the surface of the soil the fields are immediately submerged from 4 to 8 inches deep, and the water is held continuously at this depth until the crop is nearly ready to drain

for harvest. When rice is sown broadcast in the water only shallow water (2 to 4 inches deep) often is held until seeding is completed, then the depth of water is increased to 4 to 8 inches and the water is held continuously at this depth until the crop is nearly ready to drain for harvest. The continuous submergence of rice sown broadcast on the surface of the soil or in the water is very effective in controlling the growth of the early and mid-season types of water grass, but continuous submergence does not materially check the growth of the late white water-grass types. Very deep water—that is, 10 to 12 inches—does materially check the growth of the white water grasses. However, it does not prevent these grasses from emerging to the surface of the water and maturing seed. If rice is grown by continuous submergence and the white water grasses are not too thick, it seems advisable to pull them by hand to prevent them from increasing and making control by irrigation ineffective.

The white water grasses do not shatter as readily as the other forms present in the rice fields; therefore a great deal of the matured white water-grass seed is removed from the fields with the rice crop. However, enough seed does shatter to reseed the land, and it increases slowly from year to year.

When the land is submerged at the same depth there is no difference in the control of water grass, whether the rice is sown on the surface of the soil and immediately submerged or whether it is sown in the water. On rough seed beds, and on smooth seed beds to a certain extent, the submergence of the land after seeding often slacks enough clods to cover part of the rice seed. This is an important factor, for, as previously noted, rice seed covered with soil and water does not germinate well. The supply of oxygen under such conditions seems to be too low to initiate normal root development. Rice seeds covered with soil and water often rot, though some of the seeds may germinate and produce long bleached plumules (leaves) without root systems. These seedlings are unable to emerge to the surface of the soil and water. Rice sown broadcast in the water is seldom covered with soil, for the clods are slacked and the surface of the soil is leveled by the water before the seed is sown. After seeding in the water strong winds may cause the water to wave, and this movement of the water often covers some of the seed with a thin layer of fine soil particles. However, the seeds are seldom buried too deeply in this way for normal germination and root development. It requires more seed, therefore, to obtain a good stand of rice by seeding on the surface of the soil than by seeding in the water.

The results at Biggs indicate that the stands of rice obtained by seeding 130 to 135 pounds in the water are as good as those from 150 pounds seeded on the surface of the soil. If good stands are secured the yields obtained from both methods of seeding are about the same. Seeding in the water is more expensive than seeding on the surface of the soil, yet the practice of seeding in the water has increased rapidly. The reasons for this are: Less seed is required when the rice is sown in the water than if sown on the surface of the soil; the possibilities of getting good stands of rice are better from seeding in the water than from seeding on the surface of the soil, because less seed is covered with soil; rice sown in the water is protected from birds; and less labor is required to prepare a seed bed

when the rice is sown in the water, for the water slacks the clods. When the seed is sown on the surface of the soil the clods should be reduced as much as possible before seeding to reduce the danger of the seed being too deeply covered by slacked clods.

In the preparation of a seed bed on land that is to be continuously submerged, all organic matter should be plowed under. Organic matter left on the surface of the soil decomposes in and under water, and if a large quantity of such material is present it may, and often does, discolor the water upon decomposition. To a certain extent discolored water prevents the sunlight from reaching the submerged seedlings. A lack of sunlight results in weak seedlings, many of which are unable to emerge to the surface of the water, and thus poor stands are obtained. For this reason relatively clear water is helpful in obtaining vigorous seedlings and good stands.

Scum, which appears to consist of various kinds of algal growth and partly decomposed organic particles, often prevents the rice seedlings from emerging to the surface of the water. It is less troublesome on well-drained land free of vegetation than on poorly drained land. Ordinarily, scum does not develop nearly so fast at low temperatures as at high ones. Therefore, as a rule, rice should be sown as early as possible in the spring, so that the seedlings can emerge through the water before scum develops.

The formation of scum and discolored water are important factors in the control of water grass. Young water-grass seedlings under water grow much more slowly than the rice seedlings. The rice seedlings, therefore, emerge to the surface of the water in a shorter period of time than the grass seedlings. The latter often become coated with fine particles which float in the water, and this, combined with discolored water, helps to prevent such seedlings from emerging to the surface, and they usually die.

Young water-grass seedlings submerged in clear water will live for weeks, even at high temperatures, but as soon as scum develops on the water or the water becomes discolored or shaded by rice plants the water-grass seedlings bleach out, become weak, and soon die.

It is well known that sunlight furnishes the energy for growth in green plants, and if this source of energy is reduced by scum, discolored water, or shade, seedlings under water are weakened and eventually die. A rain, for some unknown reason, causes scum to be precipitated; and if seedlings of either rice or weed pests are under a scum at the time of precipitation, they usually fail to emerge. In June, 1929, a light rain precipitated scum in certain pots in which white water grass was being grown, and all the plants were killed. In this case the white water grass was controlled by water 8 to 10 inches deep in which scum had developed, whereas in other pots, free of scum, submerged at the same depths, the grass was not controlled or injured by the rain or depth of submergence.

The quantity of water required to produce a crop of rice depends on—

(1) The topography of the land. Land with natural sloughs or drainage courses passing through it requires more water than land with no natural drainage, because some water will pass through the levees into these sloughs and be lost.

(2) The character of the land. Light open soils require more water to produce a rice crop than heavy soils underlain with an impervious subsoil.

(3) The levee construction. Fields with poorly constructed outside levees lose more water by seepage than fields inclosed by well-constructed levees.

(4) The irrigator. Good irrigators appreciate the value of water and do not waste it; others apparently do not appreciate its value and often waste it. Basing water charges on the volume delivered rather than fixing them at a flat rate per acre would tend to conserve the water and to confine rice growing to the heavy-soil types, on which from 5 to 6 acre-feet of water are required to produce a rice crop.

DRAINAGE

The importance of good drainage should not be underestimated in rice production. Poorly drained land is usually expensive to cultivate, difficult to obtain good stands on, and seldom produces maximum yields. Weeds, such as cattails, umbrella plants, spike rush, and grasses, are more difficult to control on poorly drained than on well-drained land. Harvesting is usually more expensive on poorly drained than on well-drained land, and there is often a loss due to overripeness which results in shattering. Before the rice is sown or irrigated it is advisable to provide drainage for the low places in the field, so that it can be well drained during the flooding season and before harvest.

Good judgment must be used in deciding when the rice crop is ready to drain for harvest. No set rule can be given as to the proper time to drain, because so many factors must be considered. Some soils dry quickly after draining, others very slowly. It is evident, therefore, that the water should be held longer on soils that dry quickly than on those that dry slowly. As a rule, heavy soils dry slowly, but they crust or bake at the surface much more quickly than light soils. For this reason, some light soils should be drained earlier than heavy soils, because more time is required to form a crust at the surface which will support harvesting machinery. The weather has a marked influence upon the date of draining. Naturally, it takes longer for the soil to dry with poor drying weather than with good drying weather. It usually takes from 10 to 18 days after draining until the land is dry enough to support harvesting machinery. The levees should be cut in many places so that all water can be drained from the low spots in the field.

Prior to draining the land for harvest, no water should be allowed to enter the fields for about a week. This gradual lowering of the water is desirable because rapid draining has a tendency to cause lodging. Large quantities of drainage water also may damage crops located on lower lands.

Rice should be drained early enough to permit the ground to become dry, so that it will support harvesting machinery by the time the crop is practically mature. It is usually ready to drain when the panicles are well turned down and the lower kernels on the panicles are in the soft-dough stage. At this time the upper two-thirds of the kernels on the panicles are usually turning yellowish in color.

The rice varieties grown in California require about 42 days from first heading until they are mature. About 10 days elapse from the time the first panicles appear till the crop is fully headed. The first panicles are ripe about 10 days after full heading, and the crop is fully mature about 22 days after the first panicles ripen.

After the rice panicles are well turned down, they appear to mature as well in shallow as in deep water. When rice is drained too early the yield is reduced and some kernels are immature, resulting in inferior quality. When drained too late there is often a loss due to overripeness, with resulting shattering during harvest and possible lowering of quality due to sun cracking.

More rice is probably damaged in California as a result of draining too early than from draining too late. Rice drained at the right time is ready to harvest before it is overripe and yet not immature. At this stage it yields best and mills well.

Drainage ditches should be cleaned during the slack season prior to draining for harvest, so that the fields can be drained promptly if necessary.

FIGURE 9.—Binders drawn by tractors equipped with power take-off attachments harvesting rice in California

Harvesting in the mud will soon take the optimism out of an optimist and materially reduce the profits of an otherwise profitable crop.

For many years little attention was given to the drainage problem, but now several drainage districts have been organized, and considerable drainage work has been done. With better drainage the duty of water probably will be reduced.

Drains should be kept open during the winter months. This will prevent water-logging and the accumulation of alkali salts in the surface soil. Good drainage also aids in the aeration of the soil, which is distinctly beneficial to rice lands.

HARVESTING

Rice is ready to harvest usually in from 10 to 18 days after draining. At this time the panicles should be well turned down, yellowish in color, and the lower kernels on the panicles in the hard-dough stage. If harvested before this stage of development, the quality may be lowered and the yields reduced by the presence of immature

kernels. If harvested after this stage there may be a loss from shattering and sometimes from inferior quality due to sun cracking.

Binders are used in harvesting the rice crop. Some of the binders are equipped with small auxiliary engines, so that they will continue to cut even though the bull wheel slides in wet or muddy ground. In recent years fewer auxiliary engines are being used and the number of power take-off outfits is increasing. A binder drawn by a tractor and operated with a power take-off attachment gives much less trouble than the auxiliary engines do. The power take-off binders are usually 8-foot and some 10-foot cuts, whereas a 6-foot binder was formerly the most common size. (Fig. 9.)

Binders without auxiliary engines are often used on the drier ground. Most of the binders are now drawn by tractors, whereas a few years ago horses or mules were more commonly used. Push binders (binders mounted on a frame and carried in front of a

FIGURE 10.—A combine with pick-up attachment threshing rice from the swath in California

tractor) are sometimes used in "opening up" or cutting the first swath against the levees. These binders may save considerable rice. Small tractors, however, with power take-off attachments, if run on the levees, can open up a field without much loss of rice.

In 1929 and 1930 part of the California rice crop was harvested with combines (combined harvester-threshers). The rice was cut with swathers and the swaths were allowed to dry in the windrows for three or more days; then a combine with a pick-up attachment was used to thresh the rice. (Fig. 10.)

In 1929 and 1930 conditions were favorable for the use of these outfits. Some of the growers were very enthusiastic regarding them, especially for use on early-maturing rice that can be harvested in September. It is claimed that these outfits materially reduce the cost of cutting and threshing rice. In harvesting rice that had lodged, some difficulty was encountered with these machines. One grower "combined" the rice without swathing and then dried it in an artificial drier. If the rice is combined from the standing crop,

driers must be used to reduce the moisture content of the rice to a point at which it can be safely stored. The "combining" of rice may become a common practice in California, at least under certain conditions and in favorable years.

Binders and engines should be repaired before harvesting starts, so that costly delays will not be experienced after the harvesting begins. Usually one binder should be available for each 50 to 60 acres of rice.

SHOCKING

The short-grain rices are the principal varieties grown in California. When the kernel of short-grain rice is ripe, the straw and leaves are still partially green. The harvested rice should, therefore, be put in small shocks to facilitate prompt and proper curing.

FIGURE 11.—A field of shocked rice in California

About one day after rice is cut the bundles should be put in small shocks of six to eight bundles each. (Fig. 11.) The bundles should be set firmly on the butts and the shocks well built, to avoid falling or blowing over. Slow curing and protection from the sun improve the milling quality of rice. Rice shocks usually dry slowly in California and for this reason are seldom capped, for the caps delay curing too long. Capped shocks hold the moisture from dews and light showers and thus delay threshing in the morning. Capping shocks is expensive, and since the caps interfere with morning threshing and prevent the shocks from curing well in a reasonable length of time, it is best not to use them except in extremely wet weather.

It is poor practice to stand one bundle up by itself, for most of the grain is thus directly exposed to the sun, dews, light showers, and rapid drying, which may result in sun cracking and inferior milling quality.

THRESHING

In threshing rice the quantity rather than the quality of the work done in a day is too often the standard of a job. Much rice is often wasted because a suitable platform or canvas is not provided to catch the shattered grain. Separators are not well cleaned before changing from one variety to another or from farm to farm, and, as a result, varieties become badly mixed and weed seeds are scattered. Many grains are cracked and the hulls removed by the high speed of the cylinders and by improper adjustment of the cylinders and concave teeth. The cylinder teeth should center between the concave teeth. If the cylinder teeth are to one side or the other, or if the cylinder has side play, the grains of rice will be

FIGURE 12.—A thresher showing an aspirator installed, and material which it has removed from the threshed rice

cracked. Separators and tractors should be overhauled before threshing time, in order to avoid costly delays.

Rice should be threshed when the grain is hard and the straw reasonably dry. This will require from 7 to 14 days in the shock, the length of time depending upon weather conditions. Threshing early in the morning, when the grain and straw are damp, often results in poor separation and the loss of grain. Damp rice when stored in sacks may heat and serious losses may result. Careful threshing insures a better grade of rice and larger profits.

A few rice growers have installed an aspirator on their threshers. The aspirator removes weed seeds and other foreign material from the rice before it enters the sack. This improves the quality of the rice, and in damp weather tends to reduce the percentage of moisture. The material removed is not sacked unless saved for feed, and this results in a saving in the sack bill. (Fig. 12.)

Threshing sets should be located on high ground and the sacks of rice put on a bed of straw. (Fig. 13.) The high ground and straw beneath the sacks help to protect the rice in case heavy rains

occur before the rice is banked out of the field. Rice should be banked out as fast as threshed; i. e., if 1,000 sacks are threshed per day the same number should be banked out, because there is little chance to get rice out of the field at a reasonable cost after heavy rains. It can, however, be gotten to the warehouse if it is on or near a public road.

HAULING

As stated, all rice should be banked out of the field the same day that it is threshed. (Fig. 14.) It should not then be allowed to accumulate along the roadsides, but should be hauled immediately to the warehouse. The cost per sack is much less for banking out of the field and trucking to a warehouse when conditions are favorable than

FIGURE 13.—Threshing rice in California

after a heavy rain, when the fields and roads may be practically or totally impassable.

The rice crop is not saved until it is in the warehouse. In the past, during wet autumns, considerable rice has been damaged in piles along the roadsides or in the fields. This loss could have been avoided by moving the rice promptly until it was warehoused.

WEEDS

Weeds are a menace to the rice industry of California. Most of the land in rice is infested with these pests, which materially decrease yields. Plants that inhabit wet places find conditions in the rice fields ideal for their development. Most of these plants have the characteristic weed habits, which include hardiness, abundant seed production, and shattering, which make them difficult to control or eradicate.

Weeds increase the cost of production, reduce yields, and if the seeds are mixed with the threshed grain lower its price.

Weeds are introduced into the rice fields in five ways: (1) By sowing their seeds with the seed rice, (2) by floods and irrigation water, (3) by birds and other animals, (4) by the wind, and (5) by threshing outfits. Introduction by some of these methods can be avoided. Seed rice containing weed seeds should not be sown. Troublesome weeds should not be allowed to grow along canal banks or in waste places. Animals pastured on foul land should not be transferred to clean land. Threshing outfits should be well cleaned before moving from a weedy to a weed-free farm or field. When only a few weeds appear on the roads, levees, ditch banks, and in the field, they should be pulled by hand or mowed before they mature

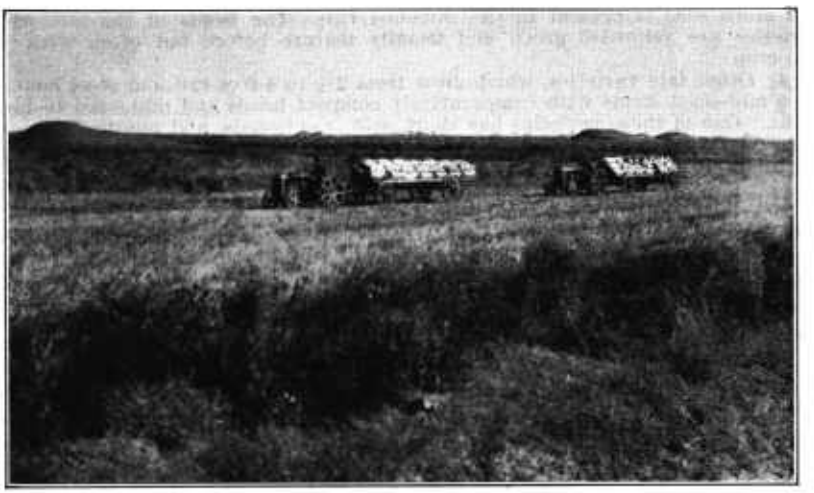

FIGURE 14.—Tractors hauling rice from thresher to roadside

seed. Weeds are well established throughout the California rice-producing area, so the problem is not, except on new or second-year land, how to prevent their introduction, but how to control or eradicate them.

The worst weeds in the California rice fields are barnyard grasses (*Echinochloa crusgalli* and varieties), cattails (*Typha latifolia*), waterplantain (*Alisma plantago*), arrowhead (*Sagittaria latifolia*), spike rush (*Eleocharis palustris*), sprangle top (*Leptochloa fascicularis*), umbrella plants (Cyperus), redstem (*Ammannia coccinea*), red rice (*Oryza sativa*), canary grasses (*Phalaris paradoxa* and *P. brachystachys*), crabgrass (*Digitaria sanguinalis*), slim aster (*Aster exilis*), chess (*Bromus secalinus*), joint grass (*Paspalum distichum*), water hyssop (*Bacopa rotundifolia*), and bulrush (*Scirpus fluviatilis*).

BARNYARD OR WATER GRASSES

Barnyard grasses (*Echinochloa crusgalli* and varieties), which are locally known as water grasses, are the most troublesome weeds in the California rice fields. There are several varieties of water grass, some bearded and others beardless. These varieties differ consid-

erably in date of maturity, height, and size of stems, heads, and seeds. For convenience in discussion of the varieties in this bulletin, they have been placed in four groups:

(1) The early red varieties which grow from 1½ to 2½ feet high, stool heavily and have small stems with rather short, compact heads and small seeds. These varieties have purplish-green stems, leaves, and heads and mature and drop most of their seed before the rice is headed.

(2) The midseason varieties, which grow from 3 to 6 feet high, stool quite heavily and have rather coarse stems with comparatively long, loose heads and mid-sized seed. These varieties usually have purplish-green stems, leaves, and heads, the purple color being less pronounced than in the early varieties. They mature and drop most of their seed before the rice crop is fully headed.

(3) The late white varieties, which grow from 2 to 5 feet high, stool heavily and have rather coarse stems with comparatively long, compact heads. One variety has large seeds, while another has much smaller seeds. The late white varieties do not shatter as readily as the two groups just mentioned, and much seed is present in the threshed rice. The heads of the late white varieties are yellowish green and usually mature before but often with the rice crop.

(4) Other late varieties, which grow from 2½ to 4 feet tall and stool heavily, have mid-sized stems with comparatively compact heads and mid-sized to large seeds. One of these varieties has short, stiff, red beards, and another is beardless. The plants and heads are about the same color as the rice. They usually mature at the same time as the rice crop.

The barnyard grasses are annuals which usually stool abundantly and produce a large number of viable seeds. These grasses are quite widely distributed in the United States and are usually found growing along sloughs, irrigation ditches, drainage ditches, on low land, and in marshy irrigated fields. They grow exceptionally well in the California rice fields.

The many varieties of barnyard grass present in the rice fields, ranging in maturity from June 15 to October 20, combined with the long growing season of rice, rather poor drainage, and the apparent ability of the grass seeds to remain in the soil from year to year until conditions are favorable for germination, make their control or eradication a very difficult problem. The problem is further complicated by the fact that much of the rice is grown by tenant farmers, who often have slight interest in preventing the spread of weeds.

In addition to the continuous submergence of rice fields to control water grasses, the methods discussed below have been and can be used to advantage in some cases.

Water grasses can be destroyed by hand pulling if cut below the crown of the plant, removed from the field, and placed on dry land. Hand weeding is practicable and profitable on new land or on land where the grass plants are few, but this method is too expensive when the grasses are thick. The grasses should be pulled at least once every three weeks from June 15 to September 15 if they are to be kept under control. When the water-grass plants are not numerous hand weeding is effective and pays. It should be rigidly practiced on new land.

Cultivated crops grown in rotation with rice, if kept free from weeds, are helpful in reducing water grasses, but usually such crops on rice lands are unprofitable.

Spring, summer, or early-fall irrigation germinates water-grass seeds, and the young plants can then be killed by shallow plowing before seed is matured. To insure germination the land should be irrigated and plowed shallow two or three times during the summer.

This method is naturally quite expensive. Deep plowing buries the water-grass seeds so deep that they do not germinate but appear to lie dormant in the soil until they are again brought to the surface by later plowing. Water-grass seeds apparently do not rot readily until after germination, and they germinate only when weather and moisture conditions are favorable.

Flooding in the fall will germinate some water-grass seed, and the plants may then be killed by frost before seed is matured.

CATTAILS

Cattails (*Typha latifolia*), locally known as tules, grow in sloughs and drainage ditches, on poorly drained land, and in rice fields. The cattail is a perennial which spreads by seeds and creeping rootstocks. The cylindrical head of the cattail, which ranges in length from 6 to 12 inches, is borne at the end of a round stalk. Each head contains thousands of seeds, which are readily spread by wind and water. Deep moldboard plowing followed by thorough drying of the soil is very helpful in the control of cattails. Good stands of rice have a tendency to prevent cattails from entering a field. They usually appear first in the rice fields in low spots or along the levees where the soil has not been well cultivated and stands of rice are poor. Disking rice stubble instead of plowing it in preparing the seed bed for rice provides favorable conditions for the growth of cattails and other weeds. Good seed-bed preparation pays, if for no other reason than that it helps to control cattails.

SPIKE RUSH

The spike rush (*Eleocharis palustris*), locally known as wire grass, grows on poorly drained land, in shallow ditches, and on field levees and establishes itself in rice fields in the corners of checks and elsewhere where cultivation and drainage are usually poor. The spike rush is a leafless perennial plant which produces seeds at the tapering end of a single round stem. The stems vary in diameter from one-sixteenth to one-eighth of an inch. The spike rush spreads by means of underground rootstocks. It will completely crowd out a good stand of rice, and the crop can not grow where the spike rush is well established. Good plowing, deep enough to get under the roots and turn them over, followed by thorough drying, is very effective in the control of this weed. The spike rush usually is not troublesome on land that is reasonably well drained and properly cultivated. Its presence in rice fields often indicates poor seed-bed preparation, poor cultural methods, or poor drainage.

WATERPLANTAIN

Waterplantain (*Alisma plantago*), locally known as waterlily, was confined for several years to the banks and edges of irrigation ditches. During the last few years, however, this weed has been increasing in the rice fields. It emerges through water as well as, or better than, rice; therefore it can not be controlled by continuous submergence. The seeds of waterplantain are reddish brown in color, and they are reported to be able to remain dormant for years and then germinate

under suitable environmental conditions. This weed appears to germinate at lower temperatures than does rice and is often present in large quantities in the intake checks where the cold water enters, and the stands of rice often are poor. In a date-of-seeding test in 1929 there was less plantain present with each successive date of seeding from early to late. It is possible, of course, that the seed was carried in with the first irrigation water and that there was less seed in the irrigation water as the season advanced. Good stands of rice help to check the stand and growth of waterplantain, which makes its best growth in thin stands of rice. Means of controlling this weed are unknown, but the germination of the seed by irrigation followed by cultivation should be helpful.

ARROWHEAD

Arrowhead (*Sagittaria latifolia*), also locally known as waterlily, is a perennial and is present to a larger extent in rice fields on the west side of the Sacramento River than in fields on the east side of this stream. During recent years this weed has been spreading in the rice fields. Like waterplantain it also makes a better growth in low places in the fields where the stands of rice are likely to be thin. It is usually rather thick along the edges of sloughs and in the deeper water. Arrowhead is easily identified by the leaves, which are shaped like arrows. Good stands of rice help to check the stand and growth of arrowhead. It is not controlled by continuous submergence. Both waterplantain and arrowhead, since they are at present increasing in the rice area, may become serious weed pests.

SPRANGLE TOP

Sprangle top (*Leptochloa fascicularis*), locally known as ray grass, grows well on low land. This grass grows about 2 or 3 feet high, stools heavily, and the fine stems terminate in a panicle. Sprangle top matures seed from June 20 to October 1. The seeds are very small and are seldom if ever found in threshed rice. Sprangle top, after it emerges, will stretch through water more quickly than rice, but it apparently does not germinate readily under water. The seeds will germinate as soon as mature. The ripe seeds of sprangle top fall to the water, germinate, and the plants die before they mature seed. Cultivation after germination will aid in controlling sprangle top, and continuous submergence usually controls it.

UMBRELLA PLANTS

Three species of umbrella plants (Cyperus), commonly known as sedges, grow in the rice fields. The perennial forms grow on the levees and ditch banks and on poorly drained abandoned land. These forms are not troublesome on well-drained land properly cultivated. On poorly prepared seed beds the perennial forms enter the checks, but improved drainage and good cultivation will rid the fields of them.

The annual form is found most abundantly in the rice checks. It does not make its appearance until after the land has been submerged for some time. Where stands of rice are thin, and sometimes in good

stands, it appears in abundance. The plants grow from 6 to 18 inches high, and a thick stand of them checks the growth of rice. No method of control is known for this form, since it appears on good and on poorly drained land, on good and on poor seed beds, and in thick and in thin stands, but it is usually thickest where the stands of rice are thin. It is most troublesome in seasons preceded by very wet spring weather.

REDSTEM

Redstem (*Ammannia coccinea*) is found in shallow drainage ditches and along sloughs, and is often present in the rice fields, especially where stands are thin. The plant consists of a single stalk, with the flowers borne at the axils of the leaves. When mature the entire plant above the ground is red in color, hence the name. The seeds are produced in a round capsule about the size of a small pea. These capsules are often present in the threshed rice and, if green, may interfere with curing in the sack. The base of the stem under water is covered with a spongelike structure. Good cultivation will doubtless control redstem.

RED RICE

Red rice (*Oryza sativa*) is usually present in all rice-producing countries of the world. It is the worst pest in the rice fields of the Southern States and has been introduced into California with seed rice. Red rice can be detected in seed rice by hulling a sample of the rough rice. Red rice has a red seed coat when the hull is removed, while the common rice has a brownish or white seed coat. Seed containing red rice should not be sown. The presence of red grains in milled rice reduces its value.

Red rice has a spreading habit of growth, while the commercial rices grow more erect. The heads of red rice are loose, open, and slightly drooping. The grain shatters readily when ripe, and in this way it spreads very rapidly. The rice growers of California should guard against the spread of this troublesome weed pest. Seed rice bought outside the State should be examined carefully for red rice before it is sown.

A red rice, locally known as Italian, which is quite different in growth habit and size of kernel from the red rice just described, is found in California rice fields. It matures earlier and has a longer grain than the ordinary red rice. Its growth resembles that of the commercial varieties of rice, but the seed shatters more readily. This red rice, like the other, lowers the commercial value of the crop, and seed rice containing it should not be sown.

In 1926, of 131 seed samples submitted to the California State Department of Agriculture for analysis, 30 contained seed of red rice. Of the 80 samples submitted in 1927, 21 contained seed of red rice. In 1923, if graded on the red rice factor only, 97.3 per cent of the California rice marketed was in grade No. 1, whereas in 1926 only 87.3 per cent was in grade No. 1. The figures for 1927 and 1928, based on the new standards, were 82.9 and 72.7 per cent, respectively. These figures show that red rice was increasing rapidly in California.

Red rice can be eradicated in California by using seed free of red rice on fallow land, as there is no evidence that red rice seed is viable after a fallow year. If the land is cropped continuously to rice and if seed containing red rice is sown the first year, it will no doubt increase with each successive year. Seed containing red rice is expensive at any price.

JOINT GRASS

Joint grass (*Paspalum distichum*) is an obnoxious perennial weed pest in the irrigation ditches and often spreads into the rice checks. It is a creeping grass which spreads rapidly by rooting at the joints or nodes. Runners from this grass may extend from the levees into a rice check for a distance of 25 feet or more, and it will grow on submerged land. It is difficult to eradicate, for it is able to withstand drought or water. Joint grass is very troublesome in irrigation ditches because of the dense growth which partially dams up the ditches unless they are frequently cleaned. It is spread by seed and sections of plants that may be carried by implements or that may float in the water. Frequent cultivation during a fallow season may be helpful in controlling this grass.

WATER HYSSOP

Water hyssop (*Bacopa rotundifolia*) is an annual plant which looks very much like water cress. In thin stands of rice water hyssop is often quite thick, and under such conditions it appears to retard the development of the rice plants. This weed, however, blooms early in the season, and when the water warms up it usually dies and the plants rot and disappear. It does not appear to be a serious weed pest except that it may check the growth of rice early in the season.

BULRUSH

Bulrush (*Scirpus fluviatilis*) was first observed in a rice field in 1929 near Cordora, Glenn County, Calif. The farmer owning the field upon which the bulrush was found stated that it appeared to be a very aggressive weed and was spreading, even though the field had been fallowed and well cultivated during the fallow year. This rush looks very much like nut grass and spreads by means of seed and tuber-bearing stolons. An effort should be made to eradicate it before it becomes more widely spread in the rice area.

CANARY GRASS

Canary grass (*Phalaris paradoxa* and *P. brachystachys*), commonly known as California timothy, germinates during the late-winter and early-spring months and by the time the land is dry enough to cultivate has often made a luxuriant growth. Unless this growth is destroyed in preparing the seed bed it often checks the growth of the rice crop. Soon after the land is submerged canary grass dies, for it is not a water plant. This grass is readily controlled by good seed-bed preparation.

CRABGRASS

Crabgrass (*Digitaria sanguinalis*) is often present on the field levees, but it seldom enters the rice checks. This grass has a spreading habit of growth and roots from the joints or nodes of the stem. It is practically impossible to pull this grass, owing to its method of rooting, but good cultivation tends to destroy it.

SLIM ASTER

Slim aster (*Aster exilis*), locally known as ironweed, grows quite thickly on rice-stubble land during the summer months when it is uncropped and not cultivated. When rice is sown on disked rice stubble, there is usually considerable slim aster in the rice crop, but this weed is easily controlled by good cultivation. Its presence in a rice field usually indicates that the crop was sown on a poorly prepared seed bed.

CHESS

Chess (*Bromus secalinus*) is not a troublesome weed in the rice fields, but often is present in rice grown on poorly prepared seed beds on which the vegetation has not been killed. Because of the difficulty of removing chess from rough or milled rice, the value of the crop is reduced. Wheat and barley are also objectionable in rough rice. Such growth therefore should be killed before the rice is sown, to avoid a reduction in the price received for the crop.

INSECTS AND OTHER PESTS

California rice fields have always been singularly free from insect enemies. None of the insects of major importance that injure rice in Louisiana, Arkansas, and Texas have been found in California fields. Grasshoppers of several species have been found feeding upon the rice leaves and the culms. The western 12-spotted cucumber beetle (*Diabrotica soror* Lec.) has also been observed in large numbers feeding on leaves and on the grain, but most of the individuals of this species seem to prefer rice pollen to other food. Leaf hoppers, flea beetles, and leaf tyers have also to a small extent been found feeding on rice. None of the pests discovered thus far have been known to cause serious damage to the rice crop. The main problem in California, therefore, is to prevent the injurious rice insects in other parts of the United States and in foreign rice-growing countries from entering the rice fields of that State.

When injury is observed and information desired, specimens of the insect causing the damage, together with a sample of the injured plant, should be sent either to the State experiment station or to the Bureau of Entomology, United States Department of Agriculture, Washington, D. C.

Blackbirds are troublesome in rice fields in the spring and fall. In the spring large flocks of blackbirds pick up the rice after broadcasting and before it is irrigated. The writer shot a number of blackbirds in the spring of 1922 and found that their crops contained from 4 to 48 kernels of rice. They no doubt consume a good deal of rice and may help to cause thin stands. They also damage the rice

after heading, when it is in the milk stage. Keeping the blackbirds away by shooting early in the morning and in the evening when they usually feed will be found helpful.

In rice fields with open water, wild ducks often cause serious damage. They alight in the open water and feed out into the rice checks. Mud hens (coots) have been rather troublesome in the rice area during 1929 and 1930. These birds alight in the open water after seeding and feed upon the soaked seed rice. They are accused of pulling up the poorly anchored seedlings following germination. Once they become established it is practically impossible to drive these birds from a field. Just how much damage they do to the stands of rice is difficult to determine.

All of these bird problems are being investigated by a representative of the Biological Survey at Marysville, Calif., with whom interested rice growers should communicate.

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